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## DESCRIPTION

PRODUCTION DEVICE AND METHOD FOR MULTICOMPONENT FILM  
AND COATED TOOL WITH MULTICOMPONENT FILM

## TECHNICAL FIELD

[0001]

The present invention relates to a production device and a production method which can more easily  
5 produce a nitride, a carbide, a boride, an oxide or a silicide containing two or more metal components such as TiAlN than prior art, and relates to a coated tool with a film formed by the production method.

## BACKGROUND ART

10 [0002]

A PVD (Physical Vapor Deposition) method has been known as a method of coating a product surface to give it abrasion resistance, oxidation resistance, corrosion resistance and other some functions.

15 An ion plating method, which is used as one of the PVD method and combines one part of a vacuum deposition method with a sputtering process, is a surface treatment method for forming a coating of a metal compound such as a metal carbide, a metal nitride  
20 and a metal oxide or a compound thereof. This method is now significant as the method of coating particularly the surface of a sliding member and a

cutting tool.

[0003]

Conventionally, a nitride containing two or more metal components such as a TiAlN film has been  
5 exclusively produced by an arc process or a sputtering process.

However, these methods need an expensive alloy target serving as a vaporizing material and need to prepare the target of a composition according to an  
10 objective film composition. Further, the methods hardly use the whole of a raw material, by reason of an electromagnetic field and a holding method of the target. In addition, the arc process inevitably involves deposition of unreacted metal droplets and can  
15 not form a film with satisfactory quality. The sputtering process can form an extremely flat film, but has generally a small film-forming rate.

[0004]

On the contrary, a melting-evaporation type  
20 ion plating method (hereafter referred to as a melting method), has an advantage of evaporating most of a charged raw material and a high material use efficiency. This is particularly advantageous when using a metal of high material unit cost or a hardly  
25 formable metal as the raw material. However, the conventional melting method has difficulty in uniformly evaporating two or more sorts of metal materials with remarkably different melting points.

[0005]

For instance, when two or more sorts of metal elements with largely different melting points such as Ti and Al are melted in the same crucible with a conventional method, Al with a low melting point precedently melts and vaporizes, and subsequently Ti does. As a result, the obtained film has a composition affected by the difference of the melting points, specifically contains a high ratio of the low-melting metal on a base metal side, and contains gradually a high ratio of the high-melting metal toward a surface layer.

Thus, the film containing two or more sorts of metal elements formed with the conventional method has a distributed composition wholly depending on their melting points, and accordingly has had difficulty in controlling the composition distribution in a film thickness direction. It was almost impossible to control the film on the base metal side so as to contain a higher ratio of the high-melting metal, and the film on the surface side so as to contain a higher ratio of the low-melting metal.

[0006]

In order to solve such a problem, a method of installing a plurality of evaporation sources in an ion plating apparatus has been adopted, for instance, as seen in JP-U-06-33956 (Fig. 1).

However, in order to provide the plurality of

evaporation sources, the ion plating apparatus needs an additional power supply. Further, In addition, a film-forming rate by the melting method depends on a distance or positional relation of the evaporation source from or with an article to be vapor-deposited, but it is difficult for the apparatus having the plurality of evaporation sources to uniformize the positional relationship between the plurality of evaporation sources and the article to be vapor-deposited. For this reason, it is almost impossible to obtain a film having a consistent composition.

#### DISCLOSURE OF THE INVENTION

#### PROBLEM TO BE SOLVED BY THE INVENTION

[0007]

Accordingly, it is desired to form a multicomponent film containing metal components such as  $\text{TiAlN}$  having greatly different melting points in adequate quality, for instance, in which each component of different metals is distributed at a desired rate over the whole film thickness. It is also preferable to form the film at high material use efficiency by using a raw material alloy which has metal components not required to be strictly matched with an objective film composition but almost close to the objective film composition, and of which the whole part can be effectively used.

The invention has an object of providing a

production device and a production method for forming such a multicomponent film and a tool coated with the film formed by using the production method.

#### MEANS FOR SOLVING THE PROBLEM

5 [0008]

A multicomponent film production device and a method according to the invention uses an alloy containing at least two sorts of metals or an intermetallic compound as a vaporizing raw material, 10 melts and evaporates the material from a single crucible or hearth with the use of plasma converged by an electric field or a magnetic field. At this time, an unmelted portion of the raw material is sequentially melted and evaporated by supplying first electric power 15 necessary for melting and evaporating the material and by supplying electric power while gradually increasing the power at predetermined intervals repeatedly up to the necessary maximum electric power. Further, the plasma is converged in a first plasma region necessary 20 to evaporate the raw material and is subsequently and sequentially moved and expanded from the first plasma region to the maximum plasma region and then, sequentially melts and evaporates an unmelted portion of the raw material.

25 [0009]

The above scheme allows a melted portion to be expanded during coating treatment for supplementing

the metal of a low melting point.

As a result, it is possible to form a film in adequate quality, in which respective metal components with greatly different melting points of a metal such as TiAlN form a desired composition distribution over the whole film thickness by controlling the composition of a starting raw material and the melting rate of an unmelted portion. The vaporizing raw material does not need to be strictly matched with an objective film composition and may be an alloy having a metal composition approximately close to the objective film composition. Furthermore, almost the whole material can be effectively used and the material use efficiency is high.

[0010]

A coated tool according to the invention has a cutting tool base material such as a high-speed tool steel, a die steel, a cemented carbide or a cermet, and the film of a nitride, a carbide, a boride, an oxide or a silicide containing a plurality of metal elements is formed on the base material by the above method according to the invention.

Thus, the coated tool with the superior film having desired composition distribution can be obtained.

MODE FOR CARRYING OUT THE INVENTION

[0011]

The invention will be now described in detail with reference to an embodiment. At the outset, the development to the invention will be described.

The present inventors attempted to form a  
5 TiAlN film under a condition of obtaining a general TiN coating with the use of 50 g of a TiAl alloy as a melting raw material. In this attempt, the TiAl alloy was totally melted in a few minutes after having started melting. The film thus obtained had a  
10 composition in which Al was abundant on a base material side and Ti was gradually abundant toward a surface side. This is because Al has a lower melting point than Ti and precedently vaporizes from the melted material, so that the film formed at first inevitably  
15 contains a high ratio of Al.

[0012]

When the coating process was further continued, Al in the raw material was exhausted and the film containing a high ratio of Ti was formed at the  
20 outermost. Thus obtained film had a low hardness and poorer adhesiveness as compared with a TiN film.

Then, the inventors considered supplying Al which was exhausted by evaporation, and conducted experiments of additionally charging Al into a melted  
25 material. However, it was difficult to balance melting and evaporation with the Al supply, and a satisfactory result was not obtained.

[0013]

According to the conventional technique, it is general to control electric power used for melting a raw material to approximately constant electric power determined to be optimum at first, except when starting  
5 melting.

The inventors inferred that if the electric power was increased in a stepped manner at predetermined intervals during the melting, an unmelted portion would newly start melting and supplement a low-  
10 melting metal contained in the unmelted portion to the film. They repeated many experiments and could prove correctness of the inference.

[0014]

Furthermore, according to the conventional  
15 technique, also in melting an unmelted portion by controlling an electric field or a magnetic field for converging plasma, it is general to control a plasma region used for melting a raw material to an approximately constant plasma region determined to be  
20 optimum at the beginning, except when starting melting.

The inventors inferred that a similar effect would be obtained by controlling the plasma so that the plasma region was continuously moved and expanded from the first region up to the maximum plasma region by  
25 sequentially moving and expanding the plasma. They repeated many experiments and could prove correctness of the inference.

[0015]

The present invention is based on such knowledge of the inventors as the above.

A production device according to the embodiment of the invention uses an alloy containing at least two sorts of metals or intermetallics compound as a vaporizing raw material, melts and evaporates the raw material to form a multicomponent film. The production device has, as shown in Fig. 1, a vacuum chamber 1 for accommodating a member to be coated or a workpiece 2, and a single crucible or hearth 3 mounted in the chamber for receiving the raw material 4. The device is further equipped with a power supply unit 6 including a HCD gun (Hollow Cathode Gun) 5, which supplies an electric power to the crucible to cause arc discharge, evaporates and ionizes the raw material by the generated heat and plasma 7, and a plasma control unit 9 including an electromagnetic coil 8 for controlling a magnetic field for converging the plasma when evaporating the raw material.

[0016]

The production device of the embodiment may have the same construction as the conventional apparatus according to the melting and evaporating type ion plating method, except the power supply unit 6 and the plasma control unit 9, and further description on the same components will be omitted.

The electric power supply unit 6 is on a sequentially-increased electric power supply system of

gradually increasing electric power to be supplied and sequentially melting the unmelted portion of a raw material.

In this embodiment, the electric power supply unit 6 first supplies electric power of 2,000 W necessary for evaporating the raw material. Then, the unit supplies electric power increased by 300 W from the electric power supplied immediately before at an predetermined interval of one minute. The electric power increased by 300 W is thus repeatedly supplied up to the necessary maximum electric power of 8,000 W, and sequentially melts the unmelted portion.

[0017]

The plasma control unit 9 similarly has a construction of changing the magnetic field control for converging the plasma when evaporating the raw material.

In the embodiment, the plasma control unit 9, at first, converges the plasma in a first plasma region necessary for evaporating the raw material, or a region with a diameter of 10 mm about an approximate center of the material. After that, the unit controls the plasma so as to sequentially move and expand it from the immediately preceding plasma region. The plasma is thus continuously and sequentially moved and expanded up to the maximum plasma region with a diameter of 40 mm almost covering the whole material, and sequentially melts the unmelted portion.

[0018]

Examples of tools with films formed by the method according to the invention will be described below.

5 [Example 1]

As a vaporizing raw material, a TiAl alloy plate having a diameter of 40 mm, which contained metal compounds almost similar to an objective film composition, was used. The material was charged into  
10 the crucible (or hearth), the workpiece was heated and cleaned, and then, the raw material was melted and evaporated in a mixture atmosphere of argon and nitrogen gases at a pressure of about 1 Pa. At this time, a HCD gun was used, which was set to converge the  
15 diameter of a plasma beam into about 10 mm on the top face of the raw material to be melted. A TiAlN film was formed from thus obtained vapor of the raw material on a high speed steel drill and a cemented carbide end mill which had a TiCN coating beforehand coated as an  
20 undercoat.

[0019]

A plasma output at this time was increased by 300 W per minute from 2,000 W to 8,000 W for 20 minutes. At the same time, the plasma control was  
25 performed so as to continuously and sequentially move and expand the diameter of the plasma beam for 20 minutes to finally cover the whole TiAlN alloy plate with the diameter of about 40 mm ultimately and to

sequentially melt the unmelted portion.

The result of a cutting test with the obtained high speed steel drill is shown in Table 1 (item name: drill life). The test was conducted to use the high speed steel drill in cutting up to the breakage life.

(Cutting condition of the high speed steel drill)

tool: high speed steel drill of  $\phi 6$

cutting method: drilling, using 5 pieces of each example

work material: S50C (hardness 210 HB)

cutting speed: 40 m/min, feed: 0.1 mm/rev

cutting length: 20 m (through hole),

lubricant: dry type (none)

[0020]

[Table 1]

	Film thickness * $\mu\text{m}$	Film hardness HV0.05	Drill life (hole)	End mill flank wear $V_B$ (mm)	Oxidization thickness $\mu\text{m}$	
TiCN+TiAlN (melting method)	Surface layer 0.9 Undercoat 1.7	3300	852	0.05	0.4	Invention
TiCN (melting method)	2.1	2800	416	17m stopped	All oxidized	Comparative example
TiCN+TiAlN (arc process)	Surface layer 1.2 Undercoat 1.9	3800	489	0.08	0.6	Comparative example

\* Film thicknesses are values measured on simultaneously installed test pieces of high speed steel (SKH51,  $Ra \leq 0.2 \mu\text{m}$ ) with a carotest method (fretting mark method).

[0021]

As is apparent from Table 1, the high speed steel drill with the hard film according to the invention shows the very long life almost twice as  
5 compared with the conventional examples. This is because the melting method forms almost no droplet and imparts small surface roughness.

According to the invention, the multicomponent film containing metal components with  
10 greatly different melting points such as TiAlN had such adequate film quality as to show the desired distribution of the respective, different metal components over the whole film thickness. Further, as for the vaporizing raw material, since it does not need  
15 to strictly match with the objective film composition, a raw alloy material having metal compounds approximately close to the objective film composition may be used and almost the whole parts of the material can be effectively used so that the material use  
20 efficiency is high.

[0022]

[Example 2]

Cemented carbide inserts (A30) were coated under the condition of Example 1 and were heated to and  
25 held at 900°C for one hour in atmospheric air. The result of measuring the thicknesses of surface oxide layers of the inserts is jointly written in Table 1 (item name: oxidization thickness). It is understood

that since the film has less film defects such as droplets as compared with that according to the arc process (the conventional example), progression of oxidation is slow and the thickness of an oxidized layer is small (improves oxidation resistance).

[0023]

[Example 3]

A cemented carbide end mill previously coated with a TiCN film in the condition of Example 1 was coated with a TiAlN film. A wear width in the flank of the cemented carbide end mill was measured after it had cut the length of 40 m, and the result is written together in Table 1 (item name: end mill flank wear). Cutting conditions are shown below.

(Cutting condition of cemented carbide end mill)

tool:  $\phi 10$  cemented carbide square end mill with two cutting edges

cutting method: downward side cutting

work material: SKD61 (hardness 53 HRC)

depth of cut: 10 mm in axial direction and 0.2 mm in diametrical direction

cutting speed: 314 m/min, feed: 0.07 mm/edge

cut length: 40 m, lubricant: none (air blow)

The cemented carbide end mill showed abrasion resistance about 10% better than a TiAlN film formed by the arc process and provided the excellent TiAlN film. Because the films have the same content, it is

considered that the improvement of the oxidation resistance by reduction of droplets contributes to this result.

[0024]

5 [Example 4]

Gear hobs were variously coated according to the claims in the condition of Example 1 and were used in dry type cutting under a condition of  $V=200$  m/min,  $f=2.2$  mm/rev and a cut length of 80 m. Table 2 shows  
 10 the result of measuring wear amounts after the cutting. The gear hob coated with the TiAlN film formed by the melting method according to the invention is reduced in crater abrasion by about 30% and in flank wear by about 8% as compared with the TiAlN film formed by the arc  
 15 process and showed extremely satisfactory abrasion resistance.

[0025]

[Table 2]

	Film thickness * $\mu\text{m}$	Crater wear KT ( $\mu\text{m}$ )	Flank wear V <sub>B</sub> ( $\mu\text{m}$ )	
TiCN+TiAlN (melting method)	Surface layer 0.9 Undercoat 1.7	8	120	Invention
TiCN+TiAlN (arc process)	Surface layer 1.2 Undercoat 1.9	12	130	Comparative example

20 \* Film thicknesses are values measured on simultaneously installed test pieces of high speed steel (SKH51,  $R_a \leq 0.2 \mu\text{m}$ ) with a carotest method (fretting mark method).

[0026]

In the above, the invention has been described with reference to the embodiment, but the invention is not limited solely to this specific form, and the described form can be variously changed or the invention may take other forms within the scope of attached claims.

For instance, although a magnetic field is used for controlling the convergence of plasma in the embodiment, it is needless to say that an electric field may be used.

#### BRIEF DESCRIPTION OF THE DRAWING

[0027]

Fig. 1 is a schematic view showing the whole configuration of a multicomponent film production device according to the embodiment of the invention.